AD NUMBER

AD482131

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; APR 1966. Other requests shall be referred to USA Aviation Materiel Command, Fort Eustis, VA 20604.

AUTHORITY

USAAMRDL ltr, 4 May 1971

AD

AD 482131

Technical Information Report 18.1.3.1

RESEARCH AIRCRAFT, XV-5A

Interim Report

April 1966

ARMY MATERIEL COMMAND

Prepared by the University of Pittsburgh
Research Staff, 1776 Massachusetts
Avenue, N.W., Washington, D.C. 20036,
under Contract DA-49-186-AMC-214(D)

DISTRIBUTION STATEMENT

SUMMARY

This report covers the background and development of the XV-5A lift-fan gas-propelled VTOL/CTOL research aircraft. The aircraft is purely experimental but its propulsion principles are considered applicable to heavier fixed-wing Army aircraft. The future of the project may be decided during 1966.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Pittsburgh Univ., Pa. Research Staff	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

RESEARCH AIRCRAFT, XV-5A

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Interim Report

5. AUTHOR(S) (Last name, first name, initial)

6. REPORT DATE April 1966	7a. TOTAL NO. OF PAGES 12	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. DA-49-186-AMC-214(D) b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) TIR 18.1.3.1 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10. AVAILABILITY/LIMITATION NOTICES This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Commanding Officer, USA Aviation Materiel Command, attn: SMOFE-AA, Fort Eustis, Virginia 20604

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Research & Development Directorate, Army Materiel Command

13. ABSTRACT

This Technical Information Report traces the development of the XV-5A research aircraft. The aircraft, though purely experimental, demonstrates the practicability of VTOL lift-fan propelled flight, combined with conversion from the VTOL mode to the CTOL mode and flight in the purely conventional mode. The XV-5A is an all-metal, twin engine, gas-propelled, subsonic, tri-fan, tricycle landing gear, VTOL/CTOL aircraft. It is 44.52 feet long. Its wingspan is 29.83 feet, and its height to the top of the vertical stabilizer is 14.75 feet. It is powered by two J85-5B turbojet engines. Its two X353-5 wing fans (lift) are 62.5 inches in diameter. Its X373-A nose fan (pitch control, and lift) is 36 inches in diameter and is located in the nose ahead of the cockpit. All fans are operated by diverting engine exhaust gases through crossover ducts to the tip turbines on the rims of the fans. Thrust louvers below the fans control the thrust generated by the revolving fans and exhaust gases. Modifications suggested as a result of tests are being made and possible military applications of lift-fan principles of propulsion to heavy aircraft are being made. The future of the project may be decided during 1966.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
*VTOL propulsion research program, Lift fan concept, Flight control in VTOL mode, *XV-5A research aircraft, *VTOL/CTOL combined flight concept, Aerodynamic research, Lift-fan turbojet propulsion, Army aircraft						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
_______________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
_______________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
_______________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

UNCLASSIFIED
Security Classification

LIST OF ILLUSTRATIONS

	Page
XV-5A in Flight with Wing Louvers, Butterfly Doors, Nose-Fan Louvers, and Pitch and Trim Controls Open	2
XV-5A Grounded, with Nose-Fan Louvers Open and Wing Air-Inflow Butterfly Doors Closed	3
XV-5A Three-View Schematic at 9,200 Pounds Gross Weight	4
X353-5 Wing Fan Propulsion System	5
XV-5A Propulsion System Concept	6
XV-5A Fan-Powered Flight Control System Operation	7

RESEARCH AIRCRAFT, XV-5A

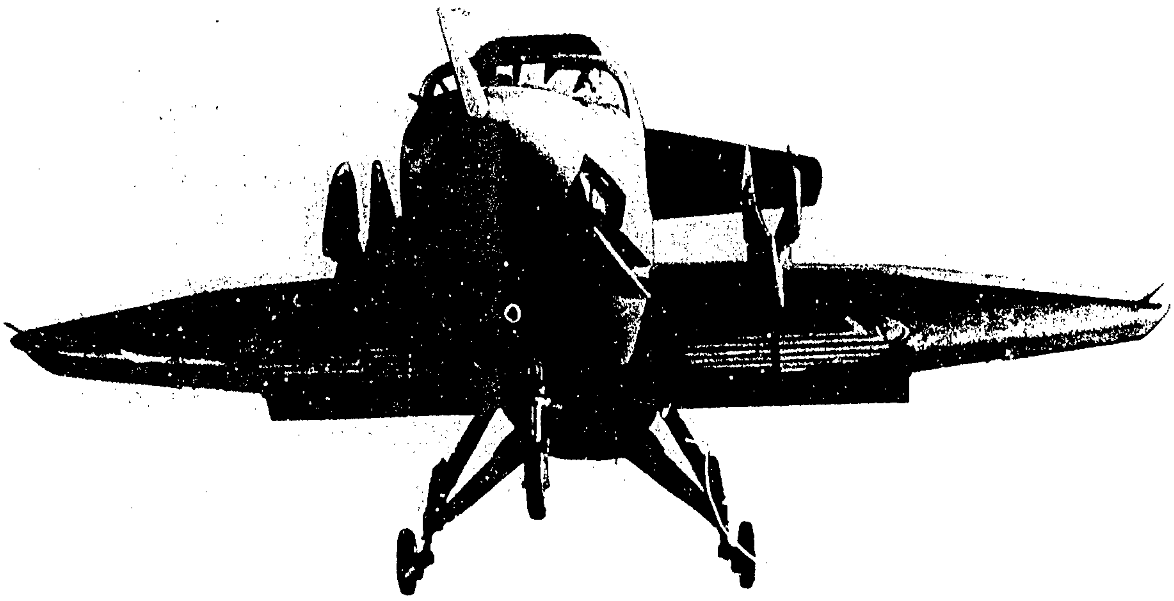
Army tactical doctrine, predicated upon the superior mobility of our forces, makes such mobility mandatory if the Army is to meet its prime responsibilities in guerrilla-type, limited, and general war. With this requirement in mind, the Army has pressed the improvement of rotary-wing aircraft in efficiency, speed, tactical applications, armaments, and so on. Possibly because of this emphasis, the advantages of high subsonic, fixed-wing, vertical and short-takeoff-and-landing (V/STOL) aircraft have not been thoroughly evaluated with respect to Army operational needs. Developments in this area, therefore, have been confined almost entirely to research, and this has been concentrated principally on combined V/STOL and conventional-takeoff-and-landing (CTOL) lift, propulsion, and flight control systems for the purpose of developing practical and flexible systems adaptable to more than one type and weight of aircraft.

The experimental XV-5A VTOL-CTOL aircraft is one of 32 such research projects, of which only two, one of them the XV-5A, may be termed a developmental, flight-tested, high subsonic aircraft. Although the XV-5A is a complete and flyable fixed-wing aircraft, it is purely experimental and was designed and built to demonstrate the performance and effectiveness of a lift-fan propulsion system operated by jet engine exhaust gases combined with normal jet-engine propulsion. The lift-fan subsystem, which has been successfully tested in the XV-5A, can be applied to military troop-and cargo-carrying aircraft with excellent chances of producing comparable levels of effectiveness.

In 1957 the Army Transportation Research Command (TRECOM) awarded a contract extending a previous contract for the continued study of VTOL propulsion systems. In 1959 another contract was awarded for a static and wind-tunnel demonstration of full-scale, tip-turbine-driven, X353-5 lift fans and X376-A pitch fans. The demonstration was successful. In 1960 scale-model tests of a proposed aircraft established the technical feasibility of the airframe and propulsion systems.

From 1957 to 1961 official Army documents, such as the Army Requirements Development Plan, 1971-75, the Research and Development Long Range Plan, 1964-1983, the reports of the Department of Defense Ad Hoc Committee on V/STOL Aircraft, the Rogers board, and the Howze board, and various Army-sponsored studies recommended research and development in the V/STOL area, with subsequent application of appropriate results to the field. On 10 November 1961 the Army awarded a development and flight research contract for an aircraft equipped with combined lift-fan vertical flight and jet engine conventional propulsion systems, limited flight control by means of fan louvers,

and a conventional flight control system. Two such aircraft were to be delivered. The specific objectives of the program were to determine and evaluate the characteristics of lift-fan-powered flight and to investigate the characteristics observed during conventional flight at high subsonic speeds.



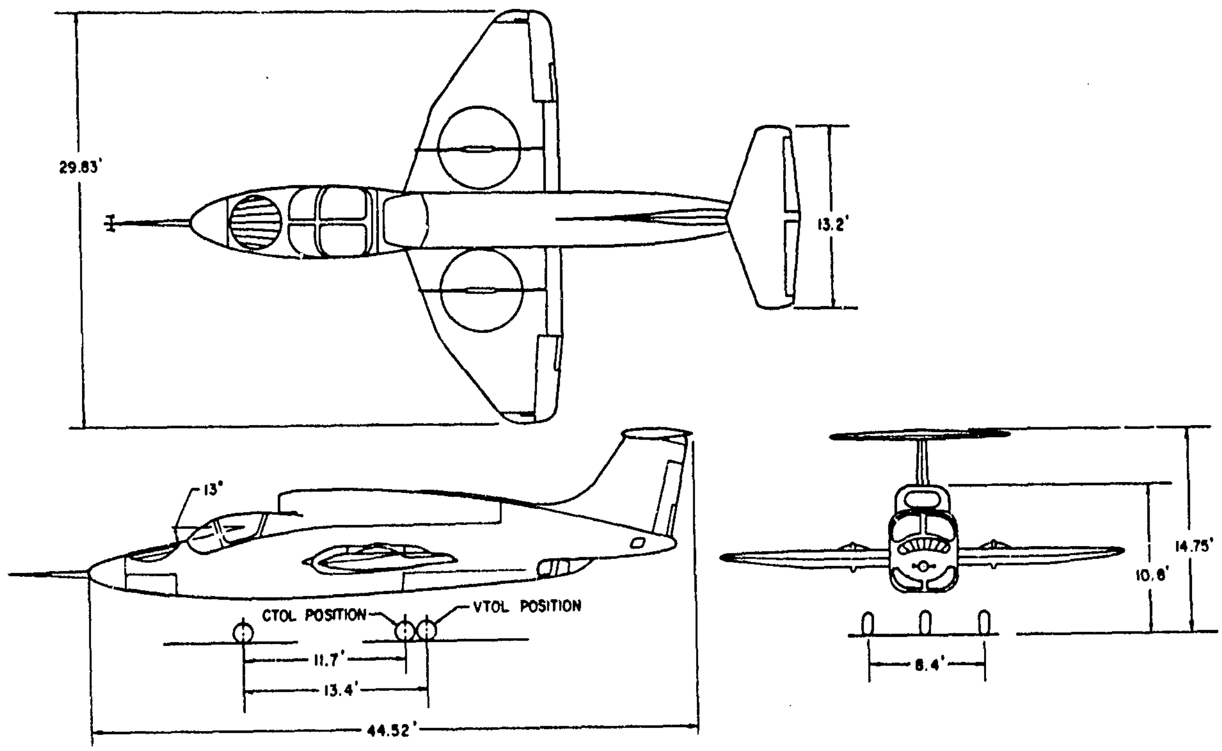
XV-5A IN FLIGHT WITH WING LOUVERS, BUTTERFLY DOORS, NOSE-FAN LOUVERS, AND PITCH AND TRIM CONTROLS OPEN

The first aircraft designed under this program, based on the requirement in paragraph 512f(1)a of the Combat Development Objectives Guide (CDOG), was designated VZ-11. This aircraft was to be powered by two J85 turbojet engines driving two X353-5 lift fans in the wings and one X376-A pitch fan in the fuselage ahead of the cockpit.

Each engine was 67.27 inches long and had a maximum diameter of 17.7 inches. The two had a combined rated thrust of 5,316 pounds at sea level on a standard day. Two counterrotating fans, each 62.5 inches in fan-tip diameter and 18.2 inches thick, were mounted in each wing. Diverter valves in the engine exhaust systems, and the fans equipped with adjustable louvers, provided controlled vertical lift. A third, 36-inch-diameter fan in the nose of the aircraft provided lift and pitch control. Thrust vectoring gave pitch-moment modulation. The lift-thrust total of engines and fans at sea level on a standard day was 12,900 pounds. Conventional mode forward speed was attained by closing off the diverter valves and the fans and operating the engines in the ordinary jet mode.

XV-5A GROUNDED, WITH NOSE-FAN LOUVERS OPEN AND
WING AIR-INFLOW BUTTERFLY DOORS CLOSED

Late in 1962 the designation VZ-11 was changed to XV-5A. Progressive modification of the VZ-11 had taken place prior to the change and similar modification of the XV-5A continued with the aim of developing a VTOL/CTOL experimental aircraft that would adequately demonstrate the lift-fan principle. In July 1963 the CDOG reference was changed to paragraphs 510b(1)b and 512g.

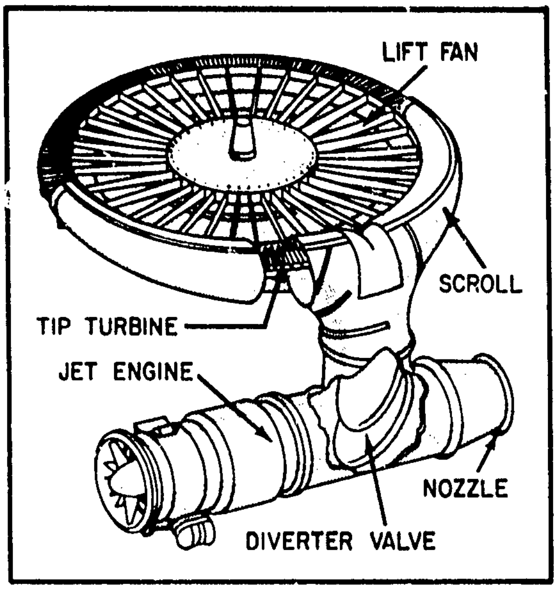


XV-5A THREE-VIEW SCHEMATIC AT 9,200 POUNDS GROSS WEIGHT

By mid-1964 two fully equipped and operational XV-5A aircraft were being flight tested by the contractor and by October 1965 the USA Aviation Test Activity at Edwards AFB, California, had completed a pilot qualitative evaluation report on their performance, which listed various advantages and some shortcomings in the configuration, flying qualities, and performance of the test aircraft. In January 1965 the CDOG reference became paragraph 533a(b).

The XV-5A VTOL/CTOL aircraft is an all-metal, midwing, twin engine, gas-propelled, tri-fan, tricycle landing gear, research aircraft. It can fly vertically and convert to, or take off in, the conventional mode. It is powered by two J85-5B turbojet engines rated individually at 2,658 pounds thrust under standard sea-level (SLS) conditions. Two diverter valves and four diverter valve actuators are provided for diverting the exhaust gases of the engines through crossover ducts to tip turbines, or "gas buckets," on the rims of all during fan-powered flight.

With a maximum gross weight of 12,000 pounds, the aircraft is 44.52 feet long, the span of its wings is 29.83 feet, and its height to the top of the vertical stabilizer is 14.75 feet. Its main landing gear can be adjusted forward or backward about 20 inches, depending upon whether takeoff is to be CTOL or VTOL, the landing gear being adjusted forward for conventional takeoff and aft for vertical flight. Tests have shown, however, that the after gear position is not required.



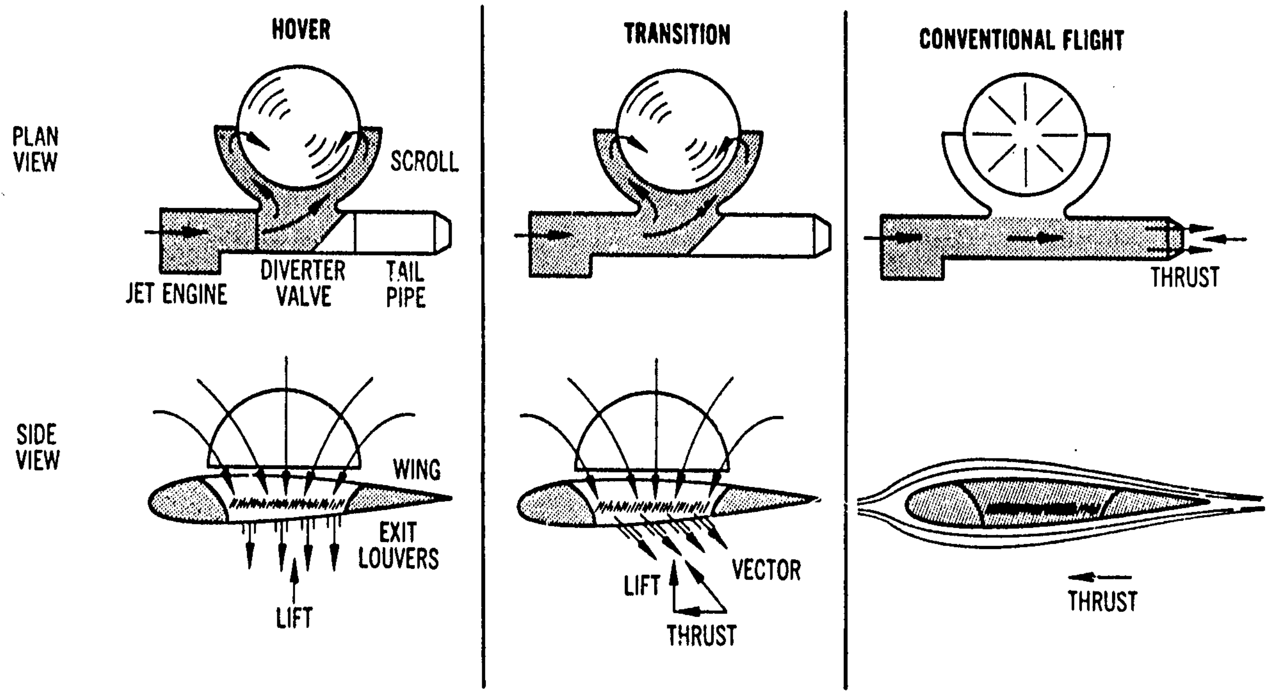
X353-5 WING FAN PROPULSION SYSTEM

The aircraft has two primary flight control systems, one fan powered, the other a conventional control system. Except for the lift control of the fan-powered system, both control systems are operated from common cockpit controls by linkage to common junctions within the fuselage. From these control junctions the linkage is branched off to serve either fan-powered or conventional flight system functions. The conventional surfaces — elevator, rudder, and ailerons — are operable at all times. The fan-powered output controls are made ineffective electromechanically during transition from fan-powered to conventional flight and remain ineffective during operation in the conventional mode.

The fan-powered primary control system is a fully powered irreversible system. Pilot commands are applied at the conventional stick and rudder pedals. Lift stick controls are applied through mechanical linkage to second-stage spools of integral hydraulic-servo valve actuators. These actuators, two in each wing and one in the nose of the aircraft, position the exit louvers on the underside of each wing and the exit doors on the nose fan. The louvers modulate high-velocity exit gases both in terms of force and of direction.

For fan-powered flight, butterfly-type air-inflow doors are opened simultaneously by means of a cluster of four linear hydraulic actuators mounted underneath the doors that provide an air-inflow path. The conversion command signal is from the pilot's mode selector switch, which actuates in sequence the horizontal stabilizer, wing-fan doors, and diverter valves. Prior to the doors' opening the signal from the cockpit preconversion switch causes the electrically operated latch on each door to release. Cockpit indicator lights indicate whether the wing-fan doors are in the fully closed and locked or unlocked position. Additional sequence limit switches are installed on the air-inflow doors. When they reach the optimum open position following establishment of the stabilizer movement rate, a diverter valve actuator is set for actuation.

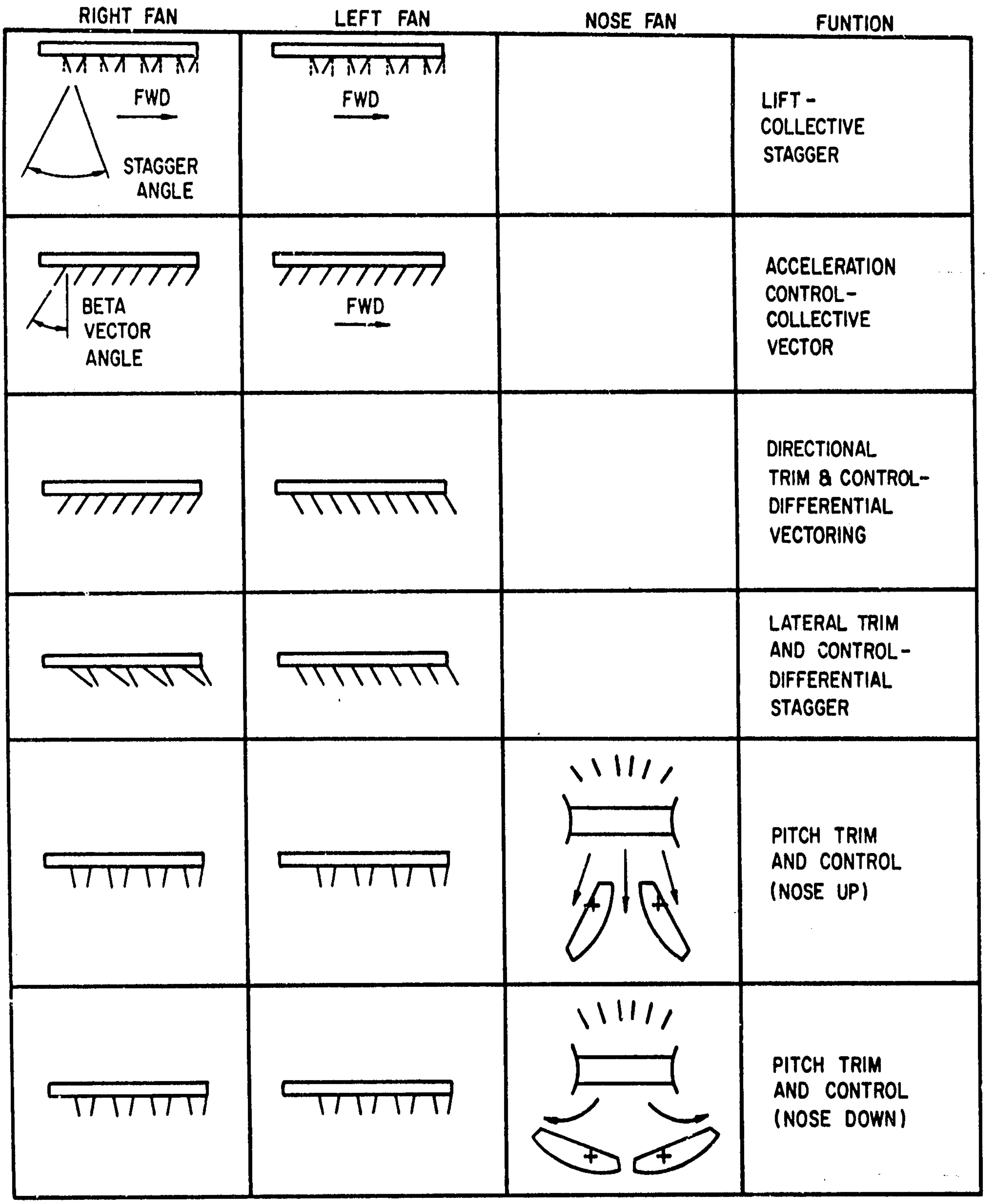
The main linkage component, between the pilot controls and wing servos that operate the exit louvers beneath the wing fans, is a mechanical mixer assembly. This assembly sums up independent pilot mechanical commands of roll, yaw, and lift, as well as electrical commands for louver-vectoring of the fan thrust. Output displacements of the assembly are fed through push-pull rods to fore-and-aft torque tubes located spanwise in each wing. Each torque tube is subsequently linked to a servo-valve actuator. The mixer also contains "feel" springs for the roll and yaw modes to provide artificial pilot "feel" during hovering. In conjunction with these spring packages, electric roll and yaw trim actuators are provided for the pilot's stick or pedal position, thereby relieving the force at these points. The trim effect is approximately 15% to 20% of the full stick or pedal effect.



XV-5A PROPULSION SYSTEM CONCEPT

The pitch-fan air-inflow louvers in the top nose surface of the fuselage open to provide the pitch fan an air-inflow path. They are controlled by means of two electric actuators mounted within the airframe, one on each side.

Each actuator operates a cluster of mechanically linked louvers to the fully opened or closed position. The actuators are electrically wired in such a way that both units must actuate limit switches on full opening prior to any further sequence action in conversion to the fan-powered mode. Actuation is initiated through the preconversion switch. A visual check is made by the pilot.



XV-5A FAN-POWERED FLIGHT CONTROL
SYSTEM OPERATION

The main linkage component between the pilot controls and the pitch-fan exit-door servo is the pitch mixer assembly located centrally in the fuselage underneath the electrical compartment. This assembly sums up independent mechanical inputs of pitch and lift control. Output displacements of the pitch mixer are fed through pushrods to the nose exit-door servo.

In conjunction with the fan-powered control system, a stability augmentation system (SAS) provides pitch, yaw, and roll rate stabilization of the aircraft. This system parallels the manual servo system in such a manner that automatically stable electric inputs to a first-stage flapper motor add to, or subtract from, the manual inputs at the second-stage spool of each servo valve. The SAS has essentially 25% of the overall mechanical authority in roll, yaw, and pitch available at 0° beta vector (Bv) (the deflection angle of the louvers) and thus can always be manually overridden either by the manual input of the servo valves alone or by its combined effect with the conventional surface deflection at other Bv conditions. Limit switches are provided on the pilot's controls to cut out automatically the integrator (position hold) of the SAS when roll commands exceed 0.75 inch of stick travel. The rate signal of the SAS is always in effect. The SAS control amplifier assembly is located in the electrical compartment aft of the pilot's compartment.

Conversion from fan-powered vertical flight to conventional flight is pilot controlled. Forward flight of the hovering aircraft is initiated when the pilot deflects the fan louvers and, if desirable, increases the engine power and flow of exhaust gases over the fan-tip turbines. This procedure is maintained until a flying speed sufficient to provide the wing lift required for sustained forward flight is attained. At that point the fan louvers, air-inflow doors, and diverter valves are closed, thus providing, in about 3.5 seconds, jet-powered forward propulsion and the conventional configuration of the wings needed for conventional flight at minimum subsonic flying speeds.

The conventional primary flight control system is a reversible mechanical system for elevator and rudder operation and a power-boost reversible system for aileron operation. Pilot commands at the conventional stick and control pedals are applied through mechanical linkages and control rods common to both the fan-powered and conventional systems. At the points of juncture (wherefrom each primary system has independent mode linkage) the rudder and elevator modes of the conventional system become essentially cable pulley systems back to their respective control surface horns. Tension regulators are installed to minimize the effects of flight structural deflections and thermal expansions. The conventional roll-mode linkage, from its point of juncture with the fan-powered roll-mode linkage, continues as a push-pull rod system. It is directly linked through the aileron droop mechanism to the aileron servo tab-and-control valve of the aileron boost actuator in each wing.

The horizontal stabilizer is actuated by means of two hydraulic motors, driving an integral self-locking screw jack. Each motor is operated from one of the primary hydraulic systems through control valves, bypass valves, and flow

restrictors. In conversion from fan-powered to conventional flight, or vice versa, the stabilizer is automatically programmed at its maximum rate to a predetermined optimum angle for either mode of flight. Limit switches at this point actuate the motor control valves to the closed position, stopping the stabilizer and deactivating the automatic conversion programming. Thereafter, the pilot can trim the stabilizer in conventional mode to any desired pitch-trim angle at a rate established by the flow restrictors and bypass valves for the mode of flight. In fan-powered flight, the stabilizer is automatically maintained at 20° leading edge up, through a vertical-takeoff-and-landing range of minus (forward deflection) 5° to plus (rearward deflection) 30° Bv of the fan louvers. Between 30° and 40° Bv, it can be trimmed by the pilot at VTOL trim rates to establish longitudinal trim prior to conversion to conventional flight, takeoff, and landing. During the conversion to CTOL, the stabilizer is automatically programmed at its maximum rate to minus 5° leading edge down. Subsequently to conversion, it can be trimmed by the pilot to desired trim angles at the established CTOL trim rate. In conversion from CTOL to VTOL, the stabilizer is automatically programmed to 10° leading edge up. At 30° Bv it is further automatically programmed to 20° leading edge up, where it remains in the VTOL mode, as mentioned above.

The aileron droop mechanism in the fuselage transmits proportional aileron droop as a function of flap deflection to provide additional lift in conventional flight. An electric screw-jack actuator, receiving the same pilot signal as that sent to the flap actuator, subsequently drives the ailerons to the desired droop angle (15° maximum). Terminal limit switches are provided for its operation. Under normal roll command, pilot input is fed directly through the droop mechanism linkage to provide opposite pushrod motion to the ailerons. The mechanism also acts as the junction of the fan-powered roll linkage to the mechanical mixer.

Conventional roll trim is provided in the left wing only by means of an electric trim actuator driving the servo tab. Conventional pitch trim is achieved through the horizontal stabilizer. Conventional yaw trim is achieved through the electric trim actuator driving the rudder trim tab. Roll, yaw, and pitch trim indicators are read out on the pilot's CTOL trim indicator.

Two XV-5A aircraft were accepted by the Army on 26 January 1965. On 28 January test flying began, and on 27 April one XV-5A was destroyed in a crash. Subsequently, all phases of the test program were completed and a pilot evaluation report was submitted on 1 November 1965. The test report listed 5 deficiencies and 11 shortcomings to be eliminated in follow-on aircraft. The aircraft was, however, found suitable for its primary mission as a research aircraft and a pilot rating of 4 (fair) was assigned its flying qualities, although it was noted that it had demonstrated "some unpleasant characteristics that cause perceptible fatigue. Precision tasks possible after additional training."

Modifications suggested by the report and others designed to improve the performance of the aircraft are now being made. Also, consideration is

is being given to possible military applications of the principles of propulsion and flight proved in the XV-5A. A decision concerning the future of the concept is expected during 1966.

MISSION PROFILES

	Nautical Miles	Knots Indicated Airspeed	Minutes
1. Hover, OGE			30
2. VTO (includes conversion to conventional flight and conventional flight)			1.0
Radius-best cruise	112	343	39.6
Loiter	—	188	5.0
Landing	—	—	2.0
3. VTO	—	—	1.0
Loiter	208	188	66.5
Landing	—	—	2.0
4. CTO	—	—	1.0
Radius-best cruise	150	343	53.0
Landing	—	—	1.0

TENTATIVE PRINCIPAL CHARACTERISTICS

Airframe, type	all-metal, midwing
Fuselage	
Length	44.5 ft (approx)
Width	4 ft (approx)
Wings	
Type	dihedral
Span	29.8 ft (approx)
Ailerons	
Span	
Hinge line	75.5 in
Trim tab	28 in
Right-side control	27° up, 18° down
Left-side control	30° up, 21° down
Droop	15° (max)
Flaps	
Type	single-slotted
Span	43% of wingspan
Control	45% down

Horizontal stabilizer	
Span	13.2 ft
Control	20°, leading edge up 5°, leading edge down
Elevators	
Span	5.5 ft per side
Control	25° up and down
Rudder	
Span	5.2 ft, parallel to hinge line
Control	25° left and right
Tread	
Main	8.4 ft
Nosewheel to main tread	
VTOL mode	13.4 ft
CTOL mode	11.7 ft
Engines	turbojet, J85-5B
Number	2
Length	67.27 in
Diameter	17.7 in
Thrust (SLS)	
Rated	2,658 lb each (5,316 lb)
Measured @ 16,500 rpm	2,852 lb each (5,704 lb)
Fans	
Type	tip-turbine
Number	
Wing	2
Nose	1
Diameter	
Wing	76 in
Nose	36 in
Thickness	
Wing	14.5 in
Nose	10 in
Speed at 100% power	
Wing	2,650 rpm
Tip-turbine	720 fps
Nose	4,650 rpm
Louvers	
Air-inflow	
Type	butterfly
Number	
Wing	1 pair per fan
Nose	to be determined
Thrust-exit	
Type	shaped
Number	
Wing	to be determined
Nose	to be determined

Lift thrust (SLS)	
Wing fans	
VTOL	6,450 lb each (12,900 lb)
CTOL	2,850 lb each (5,700 lb)
Nose fan	
(pitch and yaw control)	1,060 lb at hover
Fuel	
Internal maximum	3,250 lb
Operational hover	1,530 lb
Internal unusable	60 lb
External stores	none
Requirements	
1 min hover	87 lb/5,220 lb/hr
10 min best range	593 lb/3550 lb/hr
10 min best endurance	384 lb/2,300 lb/hr
Gross weights	
Maximum	12,500 lb
With full internal fuel	12,250 lb
With zero fuel	8,970 lb
Design hover	9,200 lb
Operational hover	10,500 lb
Empty	8,063 lb
Operational weights	
VTOL mode	12,250 lb
CTOL mode	12,250 lb
Mission fuel VTOL	2,817 lb
Mission fuel CTOL	2,817 lb
Reserve and unusable	433 lb
Limitations	
Engines	
Lift	103% @ 680° C/30 min
Thrust	103% @ 680° C/30 min
Load factor	4 to -2
Sink speed	10 fps/9,200 lb; 6 fps/12,500 lb
Angle of attack	20°
Wind	15 kn (max), all flights; 6 kn (max), VFO and hover flights only
Speed	
SLS	Mach 0.69
At altitude	Mach 0.70/25,000 ft
Gear/flap limit	180 kias
Stall-clean (normal flight configuration)	108 kias @ 10,000 lb
Stall-dirty (landing configuration)	88 kias @ 10,000 lb
Endurance	188 keas @ SLS (max)
Range	348 keas @ SLS (max)
Best climb	310 keas